Option —03
Current Shunts

603-1. INTRODUCTION

603-2. Installation of the Current Shunts module allows for current measurement in five ranges: 100 μA, 1 mA, 10 mA, 100 mA, and 1A. The 8506A DMM has dc current capability only. All other 8500 Series DMM's have both dc and ac current capabilities. For any of these DMM's, ac current measurements require installation of one of the ac converter options.

CAUTION

Selection of the autorange mode when using a constant current power source, e.g. the Fluke 3330B Constant Current Mode, can result in excessive voltage overloads. The overload results from the momentary open circuit at the DMM input terminals when ranging into or out of the 100 μA or 1A range. Constant voltage power sources are not affected.

603-3. SPECIFICATIONS

603-4. Table 603-1 lists the specifications for the Current Shunts module. These specifications cover both dc and ac current. All ac current specifications are not applicable to the 8506A. This DMM has dc current measurement capability only. All dc current specifications apply to any 8500 Series DMM. All references to the "6-1/2 digit display" apply to the 8505A and 8506A DMM's.

603-5. INSTALLATION

603-6. Refer to Section 4 of this manual under Module Installation and Removal for instructions on installing the Current Shunts module. The interconnect diagram in Section 8 contains a table listing permissible and preferred slots.

603-7. OPERATING NOTES

603-8. Operation of the front panel switches is the same as described in Section 2 of this manual. Inputs to the Current Shunts module are between Source HI and Source LO. Sense HI and Sense LO may be left connected with the shorting links provided.

NOTE

Position sensitivity of switches requires that the instrument be operated within 30° of its horizontal position.

603-9. THEORY OF OPERATION

603-10. The function of the Current Shunt module is to generate a voltage proportional to the current to be measured. Outputs from the Current Shunt module are applied either to the DC Signal Conditioner for dc currents or to an optional ac converter for ac currents.

603-11. Two modes of operation are used in the Current Shunt module, depending on the range selected. Figure 603-1 illustrates the two configurations and contains tables relating resistors, switches, and relays to each range. Mode A is used for the 100 μA, 1 mA, and 10 mA ranges. Input currents are applied to the summing node (virtual ground) of an operational amplifier through R4. R4 ensures stability when the current source is highly capacitive, while presenting a very low voltage burden. The formula given for determining floor digits (uncertainty) in the accuracy specifications is based on the feedback resistors used in the three lowest ranges. For source resistances less than approximately 10 x $R_{FEEDBACK}$, the gain of the circuit becomes greater than one for error sources such as offset voltages and current noise. Thus the basic uncertainty (digits) of a measurement increases as the source resistance decreases. The output voltage is equal to the input current multiplied by $R_{FEEDBACK}$.

Table 603-1. Current Shunts Specifications

Input Characteristics

RANGE	FULL SCALE 5½ DIGITS		RESOLUTION*		VOLTAGE BURDEN
	DC	AC[3]	6½ DIGIT	5½ DIGIT	
100 μA	250.000 μA	312.500 μA	0.1 nA	1 nA	<=100 mV
1 mA	2.00000 mA	2.50000 mA	1 nA	10 nA	<=100 mV
10 mA	16.0000 mA	20.0000 mA	10 nA	100 nA	<=200 mV
100 mA	128.000 mA	160.000 mA	100 nA	1 μA	<=200 mV
1A	1.28000A	1.28000A	1 μA	10 μA	<=500 mV

*6½ digit resolution in AVG operating mode (8505A/8506A), 100 μA ac range is 5½ digits only.

DC Current Accuracy ±(% OF READING + NUMBER OF COUNTS)*

RANGE	24 HOUR 23°C ±1°C	90 DAY 23°C ±5°C	AT SOURCE RESISTANCE[1]
100 μA	0.02 + 10	0.03 + 10	>=80 kΩ
1 mA	0.02 + 10	0.03 + 10	>=10 kΩ
10 mA	0.02 + 10	0.03 + 10	>=1.25 kΩ
100 mA	0.03 + 20	0.05 + 20	>=40Ω
1A	0.03 + 20	0.05 + 20	>=10Ω

*With 5½ digit display. For 6½ digit display multiply Number of Counts by 10.

>90 DAY 23°C ±5°C
ADD TO THE 90 DAY SPECIFICATIONS PER MONTH THE FOLLOWING % OF READING

RANGE	% OF READING
100 μA	0.0022
1 mA	0.0022
10 mA	0.0022
100 mA	0.0056
1A	0.0056

AC Current Accuracy ±(% OF READING + NUMBER OF COUNTS)[3]

24 HOUR 23°C ±1°C*			
RANGE	FREQUENCY	AVERAGE RESPONDING OPTION -01	TRUE RMS OPTION -09A
100 μA	10 Hz-20 Hz	—	0.7 + 110
	20 Hz-50 Hz	0.55 + 9	0.55 + 35
	50 Hz-10 kHz	0.3 + 9	0.28 + 35
	10 kHz-20 kHz	0.5 + 9	0.7 + 110
	20 kHz-50 kHz	1.0 + 9	1.0 + 260
	50 kHz-100 kHz	2.0 + 9	2.8 + 760
1 mA and 10 mA	10 Hz-20 Hz	—	0.7 + 110
	20 Hz-50 Hz	0.35 + 9	0.35 + 35
	50 Hz-10 kHz	0.05 + 9	0.08 + 35
	10 kHz-20 kHz	0.08 + 9	0.14 + 110
	20 kHz-50 kHz	0.08 + 9	0.2 + 260
	50 kHz-100 kHz	0.35 + 9	0.7 + 760
100 mA	10 Hz-20 Hz	—	0.7 + 150
	20 Hz-50 Hz	0.34 + 55	0.35 + 80
	50 Hz-10 kHz	—	0.18 + 80
	50 Hz-100 kHz	0.16 + 55	—
1A	10 Hz-20 Hz	—	0.07 + 160
	20 Hz-50 Hz	0.34 + 65	0.35 + 90
	50 Hz-10 kHz	0.16 + 65	0.18 + 90

*With 5½ digit display. For 6½ digit display, multiply Number of Counts by 10. Same source resistance as dc current.

Table 603-1. Current Shunts Specifications (cont)

AC Current Accuracy (cont)[3]

90 DAY 23°C ±5°C*			
RANGE	FREQUENCY	AVERAGE RESPONDING OPTION -01	TRUE RMS OPTION -09A
100 μA	10 Hz-20 Hz	—	1.0 + 110
	20 Hz-50 Hz	0.8 + 9	0.8 + 35
	50 Hz-10 kHz	0.4 + 9	0.4 + 35
	10 kHz-20 kHz	0.7 + 9	1.0 + 110
	20 kHz-50 kHz	1.5 + 9	1.5 + 260
	50 kHz-100 kHz	3.0 + 9	4.0 + 760
1 mA and 10 mA	10 Hz-20 Hz	—	1.0 + 110
	20 Hz-50 Hz	0.5 + 9	0.5 + 35
	50 Hz-10 kHz	0.06 + 9	0.11 + 35
	10 kHz-20 kHz	0.11 + 9	0.2 + 110
	20 kHz-50 kHz	0.12 + 9	0.3 + 260
	50 kHz-100 kHz	0.51 + 9	1.0 + 760
100 mA	10 Hz-20 Hz	—	1.0 + 150
	20 Hz-50 Hz	0.5 + 55	0.5 + 80
	50 Hz-10 kHz	—	0.26 + 80
	50 Hz-100 kHz	0.24 + 55	—
1A	10 Hz-20 Hz	—	1.0 + 160
	20 Hz-50 Hz	0.5 + 65	0.5 + 90
	50 Hz-10 kHz	0.24 + 65	0.26 + 90

*With 5½ digit display. For 6½ digit display, multiply Number of Counts by 10. Same source resistance as dc current.

>90 DAY 23°C ±5°C* ADD TO THE 90 DAY SPECIFICATIONS PER MONTH THE FOLLOWING % OF READING			
RANGE	FREQUENCY	AVERAGE RESPONDING OPTION -01	TRUE RMS OPTION -09A
100 μA	10 Hz-20 Hz	—	0.11
	20 Hz-50 Hz	0.089	0.089
	50 Hz-10 kHz	0.044	0.044
	10 kHz-20 kHz	0.089	0.11
	20 kHz-50 kHz	0.17	0.17
	50 kHz-100 kHz	0.33	0.44
1 mA and 10 mA	10 Hz-20 Hz	—	0.11
	20 Hz-50 Hz	0.056	0.056
	50 Hz-10 kHz	0.0067	0.012
	10 kHz-20 kHz	0.012	0.022
	20 kHz-50 kHz	0.013	0.033
	50 kHz-100 kHz	0.057	0.11
100 mA	10 Hz-20 Hz	—	0.11
	20 Hz-50 Hz	0.056	0.056
	50 Hz-10 kHz	—	0.029
	50 Hz-100 kHz	0.029	—
1A	10 Hz-20 Hz	—	0.11
	20 Hz-50 Hz	0.056	0.056
	50 Hz-10 kHz	0.029	0.029

Table 603-1. Current Shunts Specifications (cont)

Operating Characteristics

TEMPERATURE COEFFICIENT ±(% OF READING + NUMBER OF COUNTS) /°C*

0°C TO 18°C AND 28°C TO 50°C			
RANGE	DC[2]	TRUE RMS AC[3]	AVERAGE RESPONDING AC[3]
100 μA	0.0025 + 0.6	0.005 + 3.5	0.004 + 1.5
1 mA	0.0025 + 0.6	0.005 + 3.5	0.004 + 1.5
10 mA	0.0025 + 0.6	0.005 + 3	0.004 + 1
100 mA	0.0035 + 0.6	0.005 + 9	0.004 + 7
1A	0.0035 + 0.6	0.005 + 9	0.004 + 7
*With 5½ digits display. For 6½ digits display, multiply Number of Counts by 10.			

CREST FACTOR (RMS ac) ..... >4.5 at full scale, increasing down scale by $4.5 \times \sqrt{\text{I range / I input}}$

MAXIMUM OVERLOAD ..... 1.5A maximum, ±140V dc or peak ac to 60 Hz, or 200V peak ac above 60 Hz on any range with no damage. Protected by a 1.5A fuse.

SETTLING AND DIGITIZING TIME ... Same as dc volts (see Section 1).

NOTES:

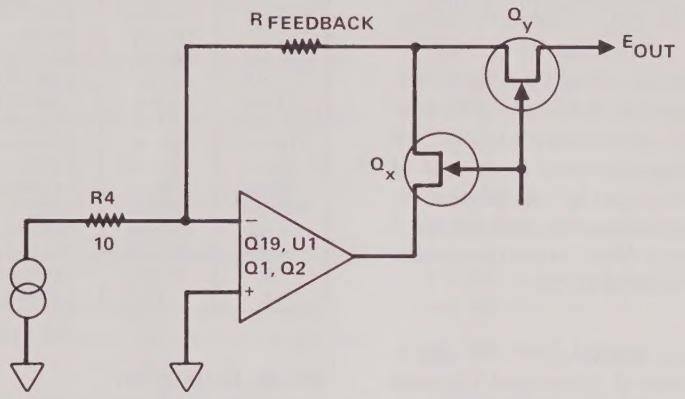
[1]For Source Resistance less than specified replace the Number of Counts in the dc Accuracy specification with the following:

RANGE	NUMBER OF COUNTS*
100 μA	9 x (1 + 8 kΩ/Rs)
1 mA	9 x (1 + 1 kΩ/Rs)
10 mA	9 x (1 + 125Ω/Rs)
*With 5½ digit display. For 6½ digits, multiply Number of Counts by 10.	

[2]For Source Resistance less than specified replace the Number of Counts per °C in the dc Temperature Coefficient specification with the following:

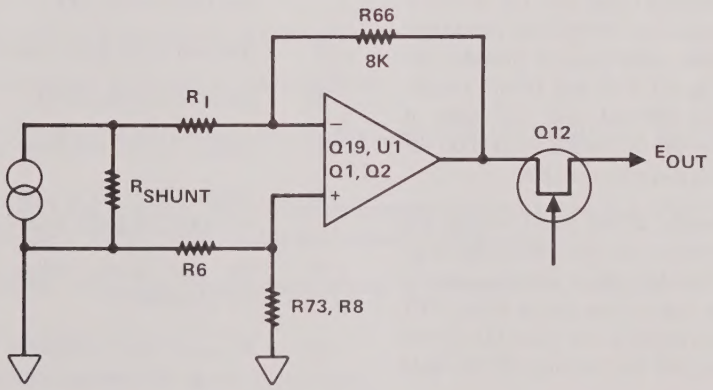
RANGE	NUMBER OF COUNTS /°C*
100 μA	0.5 x (1 + 8 kΩ/Rs)
1 mA	0.5 x (1 + 1 kΩ/Rs)
10 mA	0.5 x (1 + 125Ω/Rs)
*With 5½ digit display. For 6½ digits, multiply Number of Counts by 10.	

[3]AC Current cannot be measured with the 8506A



MODE A – 100 μA, 1 mA, 10 mA

RANGE	$R_{FEEDBACK}$	Q_X	Q_Y	RELAYS	FULL SCALE E_{OUT}
100 μA	R30, R31	Q30	Q31	K3, K4	.8 V
1 mA	R33, R34	Q7	Q10	K3, K4	1.0 V
10 mA	R36, R37	Q9	Q8	K3, K4	1.25 V



MODE B 100 mA, 1A

RANGE	R_{SHUNT}	R_I	RELAYS	FET SWITCHES	FULL SCALE E_{OUT}
100 mA	R2, R1	R7, R70, R71	K1, K3	Q20, Q32, Q29, Q12	1.6V
1 A	R1	R7, R68, R69	K2, K3	Q20, Q29, Q28, Q12	2.0V

Q11 and either Q3 or Q4 will be conducting in all ranges

Figure 603-1. Current Shunt Configurations And Range Information

603-12. Mode B configures the amplifier as a difference amplifier measuring the voltage across a shunt. The ratio of the feedback resistor, R66, to R_I sets the gain of the amplifier at approximately 20 [$R66/R_I$ = (R8 + R73)/R6].

603-13. The amplifier consists of a dual FET (Q19), U1, Q1, and Q2. Refer to the schematic. R18 biases Q19 from the −7V reference (from the A/D Converter). R57 and R58 are selected to compensate for offset error (one of them will always be 10Ω). R55 and R56 are selected for temperature coefficient compensation. Q1 and Q2 are a complementary pair (for either polarity output) to increase the current output capability of the amplifier.

603-14. Q11 and relay K3 are always closed for current measurements. Q3 and Q4 control the ground reference selection for the amplifier. In the dc mode, Q3 connects the noninverting input of the amplifier to reference common. In the ac mode the amplifier is referenced to the ac module ground (RT3) through Q4.

603-15. The Current Shunts module is addressed by IC0, 1, 3 high. At the first address, an ACK is returned and K5 is energized to sample the input voltage. If the voltage exceeds ± 45V, one section of U6 will have a high output, depending on the input polarity. The output from U6 is stored on C10. At the next address the voltage on C10 will prevent the return of the ACK response and will prevent control data from being latched into U2. An Error 4 will be displayed. In addition to overvoltage protection provided by U6, overcurrent protection is provided by CR9 and CR10 in the 100 μA, 1 mA, and 10 mA ranges, and by CR5 and CR6 in the 100 mA and 1 A ranges. A fuse in series with the Source HI terminal is located on the front panel for additional overcurrent protection.

603-16. At the second address, if the input voltage did not exceed ± 45V, termination of the address clocks range and reference control data into U2. Since relay common is Vcc, relay drivers must go low to energize a relay. FET switch drivers are configured to use a low from U2 to turn on the FET (close the switch) by turning off the gate control transistor.

603-17. MAINTENANCE

603-18. Performance Test

603-19. Test the direct current function by using the following procedure.

1. Select ADC and AUTO.
2. Connect the direct current source output HI to the instrument SOURCE HI and output LO to SOURCE LO.
3. Using Table 603-2, sequentially apply the inputs shown, manually selecting the range after the first reading. The instrument must read within the limits specified.

Table 603-2. Performance Test

Range	DC Input	Reading	
		Low (exp.)	High (exp.)
100 uA	10 uA	9.987 (−6)	10.013 (−6)
100 uA	100 uA	99.960 (−6)	100.040 (−6)
100 uA	250 uA	249.915 (−6)	250.085 (−6)
1 mA	0.1 mA	0.09987 (−3)	0.10013 (−3)
1 mA	1.0 mA	0.99960 (−3)	1.00040 (−3)
1 mA	2.0 mA	1.99930 (−3)	2.00070 (−3)
10 mA	1.0 mA	0.9996 (−3)	1.0004 (−3)
10 mA	10 mA	9.9960 (−3)	10.0040 (−3)
10 mA	15 mA	14.9945 (−3)	15.0055 (−3)
100 mA	10 mA	9.930 (−3)	10.070 (−3)
100 mA	100 mA	99.930 (−3)	100.070 (−3)
100 mA	150 mA	149.905 (−3)	150.095 (−3)
1A	0.1A	0.09975	0.10025
1A	1A	0.99930	1.00070

603-20. Calibration

603-21. Before calibrating any part of the instrument, the Calibration Memory module should be removed if installed. Apply power and allow a two hour warm-up period. All adjustments are on the Current Shunts module. DC calibration should be performed before calibrating current. Use the following procedure to calibrate the Current Shunts module.

1. Verify that the instrument is in the 1A range and the Cal mode (CAL indicator illuminated).
2. Connect the test DVM HI input lead to TP3 and the LO input to TP1.
3. The test DVM must read less than 200 mV.
4. Remove the test DVM.
5. Select the 100 mA range on the instrument.
6. Adjust R17 for a reading between -0.000-1 and +0.000-1 (0.000 ± 1 cal digit).
7. Set the current source controls for an output of 20.0000V dc.
8. Connect the instrument HI input to the current source HI output inserting a 200 kΩ ± 0.01% resistor in series with the instrument HI input lead. Connect the LO input terminal to the current source LO output.
9. Select the 100 μA range on the instrument and adjust R31 for a reading between +99.999 and +100.001.
10. Disconnect the instrument HI input lead from the current source, remove the inserted resistor and reconnect the HI input lead.
11. Select a current source output of +1.00000 mA.
12. Adjust R34 for a reading between +0.99999-0 and +1.00001-0.

13. Select a current source output of 10.0000 mA.

14. Adjust R37 for a reading between +9.9999-0 and +10.0001-0.

15. Select a current source output of 100.000 mA.

16. Adjust R71 for a reading between +99.999-0 and +100.001-0.

17. Select a current source output of 1.00000A.

18. Adjust R68 for a reading between +0.99999-0 and +1.00001-0.

19. Select the VDC function and Autorange on the instrument.

20. Select a 50V dc output from the current source.

21. Select the ADC function on the instrument.

22. ERROR 4 is displayed to show excessive voltage in the current function.

603-22. Troubleshooting.

603-23. Troubleshooting procedures for the Current Shunts module follow the format used for the mainframe instrument. Table 603-3 assures that the problem is in the Current Shunts module. Figure 603-2, Symptom Analysis, lists symptoms and possible failures in the order of probability. Table 603-4 contains address and data information used to set up the module.

603-24. Always remove power before removing or installing modules.

603-25. PARTS LIST

603-26. Table 603-5 is a parts breakdown for the Current Shunts module. Refer to Section 5 of this manual for ordering and use code information.

Table 603-3. Current Shunts Isolation

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
1	Perform DC Volts test (Section 4). Is DC within tolerance?	2	Section 4
2	Perform Current test. Is Current within tolerance?		3
3	Remove all optional modules except Isolator and Current Shunts. Is Current now within tolerance?	4	5
4	Replace modules one at a time, testing Current between modules. Last one in when Current goes bad is faulty. Go to appropriate subsection of Section 6.		
5	Remove Isolator. Install Interconnect/Monitor pcb. Is Current within tolerance?	6	7
6	Bad Isolator. Go to subsection 608.		
7	Bad Current Shunts module. Go to figure 603-2.		

SYMPTOM	POSSIBLE FAILURE
Zero noisy or out of tolerance	Q21, Q20, Q29, U1, Q3, Q4, leaky output FETS
No zero reading	K3, K4, Q19, U1, Q1, Q2
Always zero	K3 or Q11 open
100μA, 1 mA, 10 mA ranges bad, others OK	K4 open, Q29, Q20, leaky protection diodes
100 mA, 1 A ranges bad, others OK	Q20, Q29, leaky protection diodes, Q12
High random – full-scale readings	Q19, U1, Q1, Q2
No display	U5, U2
No ACK – Error 9 or Error 4	Voltage limit circuit, U6 or leaky diode (CR14, CR15), U5, Q18
Only 100 μA range bad	Q30, Q31, Digital Control
Only 1 mA range bad	Q7, Q10, Digital Control
Only 10 mA range bad	Q8, Q9, Digital Control
Only 100 mA range bad	K2, Q32, Digital Control
Only 1 A range bad	K2, Q28, Digital Control

Q19 DC Readings with Zero Input

Drains (10Ω resistors) ≃ –0.6 V dc
Sources (40 KΩ resistors) ≃ 8.0 V dc
U1 pin 6 ≃ 0V dc

Differences between ADC and AAC

1. AC/DC Reference (ground)
2. Frequency response in AAC
3. RT1 outputs are applied to DC Signal Conditioner for DC and to optional AC module for AC (DC Signal Conditioner bypassed)

If Q19, R15, R16, R55, or R56 are replaced, it is necessary to return the module to the factory (attn: PARTS) for temperature compensation.

Figure 603-2. Symptom Analysis

Table 603-4. Address and Data Field

Address – IC0, 1, 3 High						
	ID0	ID1	ID2	ID3	ID4	ID5
Current LO Input (K3) and Output FET (Q11)	X	X	X	0	X	X
DC Reference (Q3)	0	X	X	0	X	X
AC Reference (Q4)	1	X	X	0	X	X
100μA Range	X	1	1	0	1	1
1 mA Range	X	1	1	0	0	1
10 mA Range	X	1	1	0	1	0
100 mA Range	X	1	0	0	1	1
1A Range	X	0	1	0	1	1
Voltage Check	0	0	0	0	0	0
Reset	1	1	1	1	1	1

Table 603-5. Current Shunts Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
-03	Ⓐ CURRENT SHUNTS PCB ASSEMBLY FIGURE 603-3 (MIS-4104T)	ORDER	BY	OPTION -03			
C1, C2	CAP, TA, 0.47 UF +/-20%, 35V	161349	56349	196D474X0035HA1	2		
C3	CAP, MICA, 47 PF +/-1%, 500V	284802	72136	DM15E470F	1		
C4	CAP, MICA, 150 PF +/-5%, 500V	148478	72136	DM15F151J	1		
C5, C6	CAP, MICA, 100 PF +/-5%, 500V	148494	72136	DM15F101J	2		
C7	CAP, CER, 1200 PF +/-20%, 100V	358283	80031	2222-630-01-122	1		
C8, C9	CAP, MICA, 39 PF +/-5%, 500V	148544	72136	DM15E390J	2		
C10	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D475X0025KA1	1		
C11	CAP, TA, 220 UF +/-20%, 6V	408682	56289	196D227X0006TE4	1		
C12, C13	CAP, CER, 0.22 UF +/-20%, 50V	309849	71590	CW30C224K	2		
C14	CAP, MICA, 390 PF +/-5%, 500V	148437	72136	DM15F391J	1		
C15-C17	CAP, TA, 10 UF +/-20%, 15V	193623	56289	196D106X0015A1	3		
CR1-CR4	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	14	4	
CR5-CR10	DIODE, SI	680447	14552	MT2061A	6	2	
CR11	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR12	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR14	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR15	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR16	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR17	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR18	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR19	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR20	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR21	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
CR22	DIODE, ZENER	325803	07910	TD333408	1	1	
H1	SCREW, PHP, 4-40 X 3/8	256164	89536	256164	1		
K1	RELAY ASSY						
	COIL, REED RELAY	269019	71707	U-6-P	5		
	SWITCH, DRY REED	602714	15636	V1101	5		
K2	RELAY ASSY						
	COIL, REED RELAY	269019	71707	U-6-P	REF		
K3	RELAY ASSY						
	COIL REED RELAY	269019	71707	U-6-P	REF		
K4	RELAY ASSY						
	COIL, REED RELAY	269019	71707	U-6-P	REF		
K5	RELAY ASSY						
	COIL, REED RELAY	269019	71707	U-6-P	REF		
MP1	CASE ASSEMBLY	459008	89536	459008	1		1
MP2	CASE HALF, MODULE	402990	89536	402990	REF		
MP3	CASE HALF, MODULE	402990	89536	402990	REF		
MP4	COVER, MODULE, CASE	402974	89536	402974	REF		
MP5	SHIELD, COVER	412015	89536	412015	REF		
MP6	DECAL, CURRENT SHUNTS ASSY	413419	89536	413419	REF		
MP7	DECAL, CAUTION	454504	89536	454504	REF		
MP8	GUARD, REAR	383364	89536	383364	REF		
MP9	GUARD, FRONT	383356	89536	383356	REF		
MP10	SOCKET, COMP. LEAD (not shown)	343285	27264	02-09-2133	10		

Table 603-5. Current Shunts Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
MP11	SPACER, COMPONENT (not shown)	296319	32559	T0806	10		
MP12	SPRING, COIL (not shown)	424465	83553	C0120-014-0380	1		
MP13	SPACER, STANDOFF (not shown)	335604	89536	335604	1		
Q1	XSTR, SI, NPN	218396	04713	2N3904	13	3	
Q2	XSTR, SI, PNP	195974	04713	2N3906	3	1	
Q3	DIODE, HI-SPEED, SWITCHING	203323	07910	1N4448	REF		
Q3, Q4	XSTR, FET, N-CHANNEL	261578	89536	261578	13	3	
Q5, Q6	XSTR, SI, NPN	218396	04713	2N3904	REF		
Q7-Q10	XSTR, FET, N-CHANNEL	261578	89536	261578	REF		
Q11	XSTR, FET, N-CHANNEL	393314	89536	393314	1	1	
Q12	XSTR, FET, N-CHANNEL	261578	89536	261578	REF		
Q13-Q16	XSTR, SI, NPN	218396	04713	2N3904	REF		
Q17	XSTR, SI, PNP	195974	04713	2N3906	REF		
Q18	XSTR, SI, PNP	226290	04713	MPS3640	1	1	
Q19	XSTR, FET, DUAL, N-CHANNEL (SELECTED)	267963	89536	267963	1	1	
Q20	XSTR, FET, N-CHANNEL	261578	89536	261578	REF		
Q21-Q23	XSTR, SI, NPN	218396	04713	2N3904	REF		
Q25-Q27	XSTR, SI, NPN	218396	04713	2N3904	REF		
Q28-Q32	XSTR, FET, N-CHANNEL	261578	89536	261578	REF		
Q33	XSTR, SI, PNP	195974	04713	2N3906	REF		
R1	RES, WW, 0.1 +/-0.05%, 1/2W	374611	89536	374611	1		
R2	RES, WW, 0.7 +/-0.1%, 1/4W	440404	89536	440404	1		
R3	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	23		
R4	RES, MTL. FILM, 10 +/-1%, 1/8W	268789	91637	MFF1-8A100F	4		
R5	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R6	RES, MTL. FILM, 383 +/-1%, 1/8W	375899	91637	MFF1-88380F	1		
R7	RES, WW, 419 +/-0.1%, 2W	440883	89536	440883	1		
R8	RES, MTL. FILM, 7.87K +/-1%, 1/8W	294934	91637	MFF1-87871F	1		
R9-R14	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R15, R16	RES, WW, 40K +/-0.1%	271403	89536	271403	2		
R17	RES, VAR, CERMET, 10 +/-20%, 1/2W	344135	75378	190PC100B	1		
R18	RES, MTL. FILM, 19.1K +/-1%, 1/8W	234963	91637	MFF1-81912F	1		
R19	RES, DEP. CAR, 1K +/-5%, 1/4W	343426	80031	CR251-4-5P1K	2		
R20	RES, DEP. CAR, 18K +/-5%, 1/4W	348862	80031	CR251-4-5P18K	2		
R21	RES, DEP. CAR, 1K +/-5%, 1/4W	343426	80031	CR251-4-5P1K	REF		
R22	RES, DEP. CAR, 18K +/-5%, 1/4W	348862	80031	CR251-4-5P18K	REF		
R23, R24	RES, DEP. CAR, 39 +/-5%, 1/4W	340836	80031	CR251-4-5P39E	2		
R25-R29	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R30	RES, WW, 7975	440909	89536	440909	2		
R31	RES, VAR, CERMET, 50 +/-20%, 1/2W	267815	75378	190PC500B	1		
R32	RES, WW, 1020 +/-0.05%, 0.2W	440891	89536	440891	1		
R33	RES, MTL. FILM, 47.5K +/-1%, 1/8W	289546	91637	MFF1-84752F	1		
R34	RES, VAR, CERMET, 10K +/-20%, 1/2W	267880	75378	190PC103B	1		
R35	RES, WW, 128 +/-0.05%, 0.2W	440875	89536	440875	1		
R36	RES, MTL. FILM, 4.99K +/-1%, 1/8W	168250	91637	MFF1-84991	1		
R37	RES, VAR, CERMET, 1K +/-20%, 1/2W	267856	75378	190PC102B	1		
R38	RES, DEP. CAR, 150 +/-[illegible], 1/4W	343[illegible]	80031	CR251-4-5P150F	1		

Table 603-5. Current Shunts Assembly (cont)

REF DES		DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
R39		RES, DEP. CAR, 20K +/-5%, 1/4W	441477	80031	CR251-4-5P20K	5		
R40		RES, MTL. FILM, 49.9K +/-1%, 1/8W	268821	91637	MFF1-84992F	1		
R41, R42		RES, MTL. FILM, 100K +/-0.5%, 1/8W	291054	91637	MFF1-81003D	2		
R43		RES, COMP, 10M +/-10%, 1/2W	108142	01121	EB1061	2		
R44		RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R45		RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	1		
R46, R47		RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R48		RES, MTL. FILM, 150K +/-1%, 1/8W	241083	91637	MFF1-81503F	1		
R49-R52		RES, DEP. CAR, 20K +/-5%, 1/4W	441477	80031	CR251-4-5P20K	REF		
R53		RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R54		RES, MTL. FILM, 13K +/-1%, 1/8W	335539	91637	MFF1-81302F	1		
R55		RES, SELECTED				2		2
R56		RES, SELECTED				REF		
R57-R59		RES, MTL. FILM, 10 +/-1%, 1/8W	268789	91637	MFF1-8A100F	REF		
R60		RES, DEP. CAR, 5.6K +/-5%, 1/4W	442350	80031	CR251-4-5P5K6	1		
R61		RES, COMP, 10M +/-10%, 1/2W	108142	01121	EB1061	REF		
R62-R65		RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R66		RES, WW, 7975	440909	89536	440909	REF		
R67		RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R68		RES, VAR, CERMET, 5K +/-20%, 1/2W	267872	75378	190PC502B	2	1	
R69		RES, MTL. FILM, 12.4K +/-1%, 1/8W	261644	91637	MFF1-81242F	1		
R70		RES, MTL. FILM, 13.3K +/-1%, 1/8W	296566	91637	MFF1-81332F	1		
R71		RES, VAR, CERMET, 5K +/-20%, 1/2W	267872	75378	190PC502B	REF		
R72		RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R73		RES, MTL. FILM, 100 +/-1%, 1/8W	168195	91637	MFF1-81000F	1		
R74		RES, DEP. CAR, 6.8K +/-5%, 1/4W	368761	80031	CR251-4-5P6K8	1		
TP1-TP3		TERMINAL, TURRET	179283	88245	2010B-6	3		
U1		IC, LIN, OP AMP	483495	12040	LM318H	1	1	
U2	Ø	IC, C-MOS, HEX "D" FLIP FLOP	404509	12040	MM74C174N	1	1	
U3	Ø	IC, C-MOS, HEX, INVERTER/BUFFER	381848	02735	CD4049AE	1	1	
U4		IC, TTL, HEX INVERTER, BUFFER/DRIVER	327775	01295	SN7416J	1	1	
U5	Ø	IC, C-MOS, TRIPLE, 3-INPUT NAND GATES	375147	02735	CD4023AE	1	1	
U6		IC, LIN, OP AMP, DUAL	418566	12040	LM358N	1	1	
U7	Ø	IC, C-MOS, QUAD, 2-INPUT NOR GATES	355172	02735	CD4001AE	1	1	

1 ORDER P/N 459088 FOR COMPLETE MODULE CASE ASSY., WITHOUT PCB ASSY.

2 RESISTORS ARE TEMPERATURE COMPENSATED AND MUST BE RETURNED FOR RESELECTION IF ANY REQUIRE REPLACEMENT. (R55 AND R56)

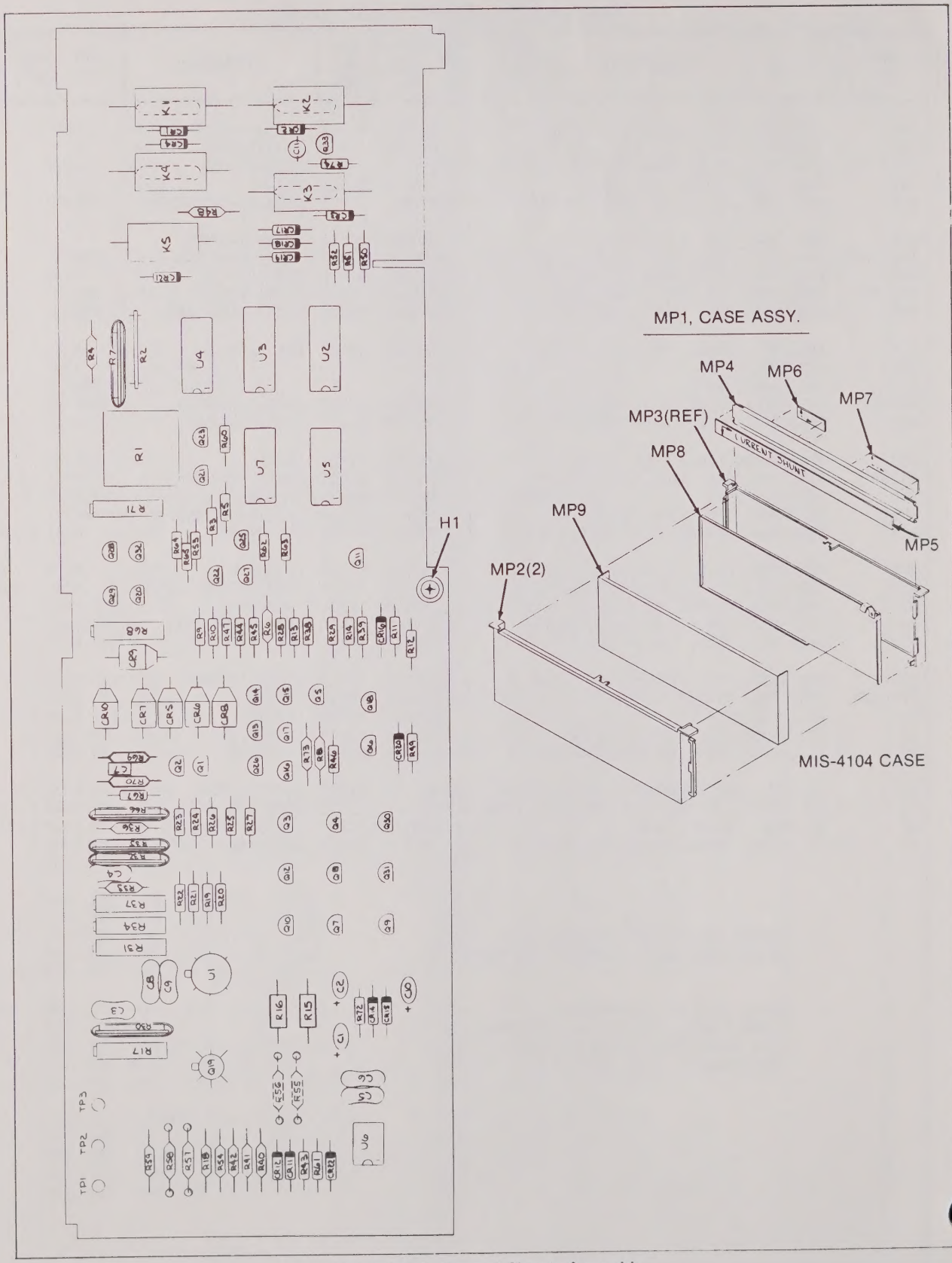


Figure 603-3. Current Shunts Assembly

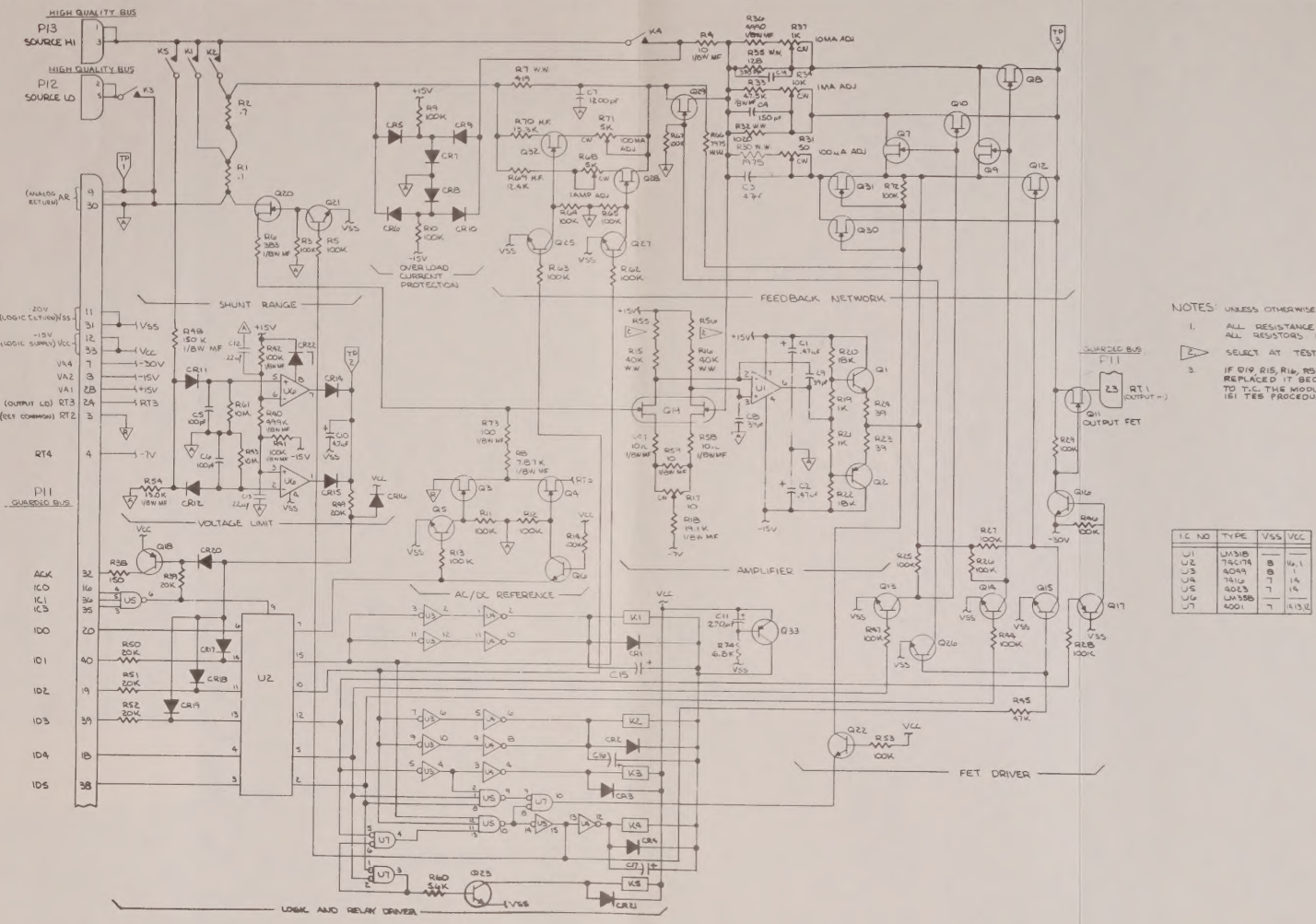
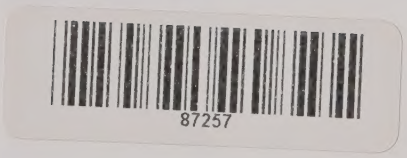


Figure 603-3. Current Shunts Assembly (cont)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